O A L S BULLETIN 12

APPLICATIONS OF REMOTE SENSING TECHNIQUES TO COUNTY LAND USE AND FLOOD HAZARD MAPPING

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A Report of Work Performed Under
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In Cooperation with
Apache, Graham, Yavapai, and Yuma Counties

OFFICE OF ARID LANDS STUDIES
University of Arizona
Tucson, Arizona

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FOREWORD

This Bulletin is published in furtherance of the purposes of NASA grant NGL 03-002-313 to the Applied Remote Sensing Program (ARSP). The purpose of the grant is to assist with the use of NASA high-altitude photography, satellite imagery, and other remotely sensed data, the governmental agencies within Arizona.

This report is the twelfth in a series of publications designed to present information bearing on remote sensing application in Arizona. The study details the land use and flood hazard mapping completed by the Applied Remote Sensing Program at the request of the Graham, Yuma, Yavapai, and Apache County Planning Departments. The purpose of the study was to delineate areas subject to periodic flood inundation and obtain accurate land use maps to monitor growth within the counties.

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INTRODUCTION

Recent state and federal legislation has made the mapping of flood prone areas mandatory for federal flood insurance purposes. This coupled with the continued pressure for development of floodplains prompted Graham, Yuma, Yavapai, and Apache Counties to seek maps of flood prone areas and current land use.

Local governmental planning agencies have traditionally regulated the design of new subdivisions by adoption of local regulations which sometimes require (among other considerations) minimum drainage design criteria. Due to passage of the mandatory floodplain regulations at the state level, local planning agencies are now faced with the task of the delineation of floodplains. Remote sensing systems offer a dynamic resource inventory system which can be used to complement traditional detailed studies or serve as an important source of information in regions where detailed studies are not available. In Graham, Yuma, Yavapai, and Apache Counties remote sensing techniques have provided hydrologic information in areas where planning had been hampered by the lack of suitable hydrologic data. The County Planning Departments can now, with only limited funds and manpower, guide development more wisely away from flood prone areas.

Methods and Procedures for Floodplain Delineation

Certain areas within each of the four counties (Figure 1) were selected as priority areas for intensive floodplain mapping. Parameters for selecting priority areas were those areas of special interest to the county planning staff and the combination of areas of imminent or ongoing development and areas known to be subject to inundation by storm runoff.

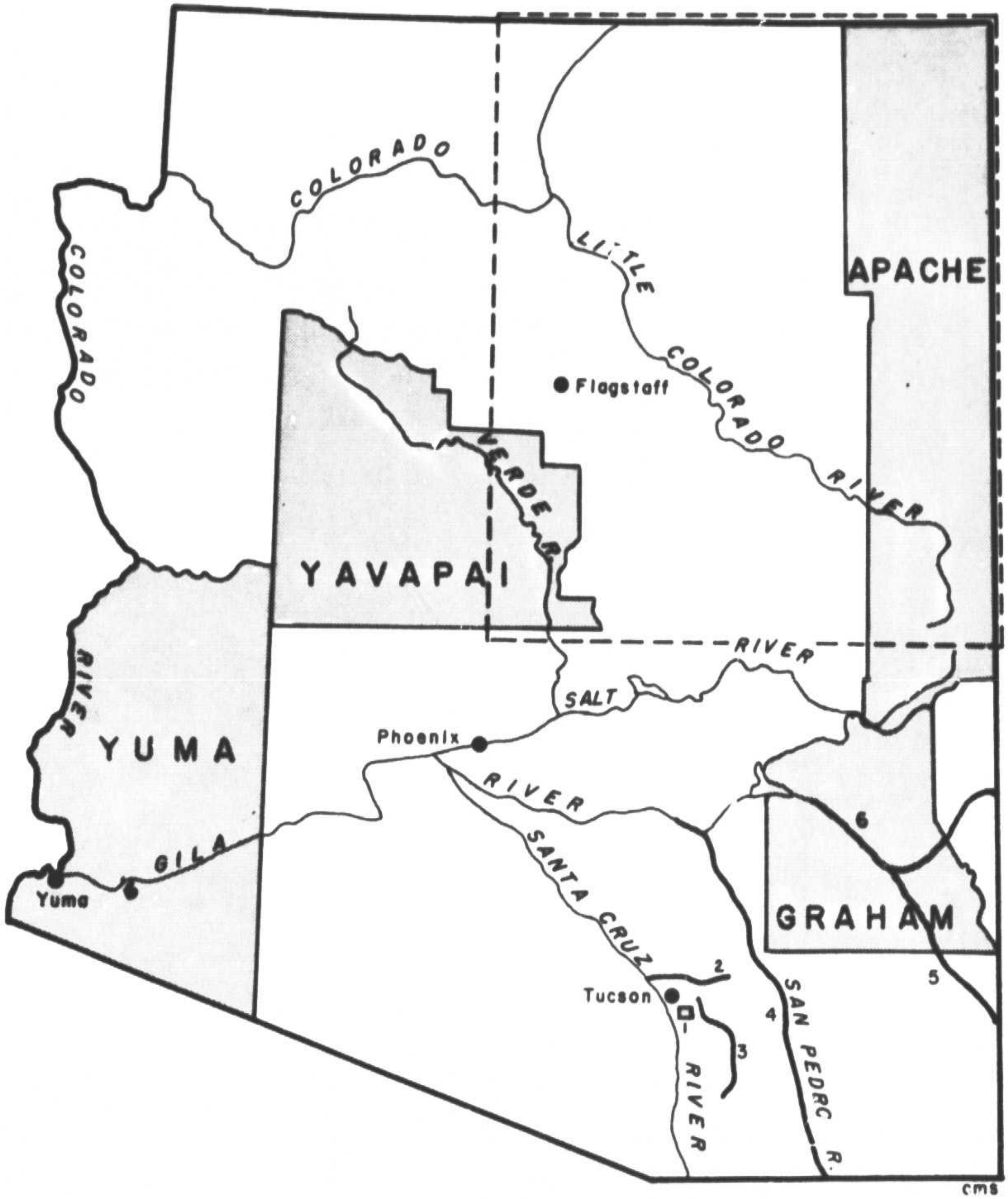


Figure 1. ARSP Project Areas in Arizona 1974-75

"Priority areas" refer to entire watersheds or significant portions thereof. Very little data were available on the watershed characteristics and stream flow of the priority areas and the information available from various sources was not in agreement regarding boundaries. Existing data were therefore used only for backup and cross reference for the remote sensing-derived-watershed and flood boundaries.

The use of remote sensing for drainage pattern and watershed configuration analysis necessitates the examiniation of soil color, texture, image appearance, and vegetation. Field checking served as the main backup to the interpretations.

Soils

A USDA, Soil Conservation Service General Soils Map is of considerable use in floodplain delineations. Soils associated with channels and low terraces are young with little or no subsurface development. The B horizon, an area of illuvial clays and blocky structure that is typical of older, more mature soils, is not present in low terrace and channel soils. These soils have a very high reflectance on LANDSAT MSS 4, 5, and 6, and color infrared photographs. The general soils map of the four counties delineate these soils as a Torrifluvents and River Wash Colluvium Association. Field checking can therefore be held to a minimum by using a General Soils Map as a reference.

Areas of periodic inundation, the so-called 25, 50, and 100 year flood events, are also associated with young soils that lack B horizon development. However their reflectance on LANDSAT bands 4, 5, and 6, and color infrared photographs has a darker tone than the channel and low terrace soils and they can be readily identified and mapped separately.

In areas of overgrazing the loss of vegetation combined with a slope of 2 or 3 percent results in sheet flow erosion. This is caused by water coalescing into a "sheet" that may be several hundred meters wide and 10 to 20 centimeters deep.

This erosion strips off the surface soil to varying depths. Sheet flow causes a very light reflectance on LANDSAT bands 5 and 7 and color infrared photographs. This tonal reflectance is different from the reflectance received from floodplains and channel soils making it possible to map boundaries of past flood events of various magnitudes using the reflectance received from all 3 soil types.

Geomorphology

The LANDSAT color infrared imagery (bands 4, 5, and 7) were used to compile a watershed map of the priority areas. The imagery was used in the form of 70mm chips for enhancement in a color additive viewer and in all available enlargement modes. The transparencies were viewed in color enhancement and on the light table in order to construct a map of watershed configuration at a scale of 1 62,500. Drainage patterns and erosional features interpreted from LANDSAT imagery at 1:250,000 was found to be nearly equal in accuracy to the output of a similar analysis of the high-altitude color infrared transparencies.

Vegetation

Vege ation was useful in mapping flood prone areas. Dominant vegetation types for a ven area are associated with soils, moisture, and climate. The vegetation analysis consisted of two parts:

1) The classification of vegetation (Table 1)
2) The determination of percent cover.

High altitude aircraft photography at a scale of 1:120,000 and LANDSAT imagery at a scale of 1:500,000 were employed in mapping the vegetation (Figures 4, 5, and 11). The aerial photography was necessary for the detailed delineations of the smaller channels.

Table 1. General Vegetation Classification of the Study Area

Desert Brush - includes mesquite, creosote bush, catclaw, ocotillo, and numerous species of cactus. Cottonwood, willow, and tamarisk trees occur along the larger stream channels. Desert brush is typical of lower elevations and low annual rainfall.

Herbaceous - typical grasses include: grama grasses, three-awn, sacaton, lovegrass, and muhly. Common shrub species found include: whitehorn, snakeweed, burro weed, agave, mesquite, and assorted cacti.

Mountain Brush - includes mixtures of oak, aspen, mountain mahogany, manzanita, bitter brush, maple, etc. This group is typical of intermediate elevations and generally higher annual rainfall than herbaceous areas.

Juniper/Grass - includes mixtures of juniper, oak, and walnut, with various grasses that are generally denser than desert grasses due to higher annual precipitation. The Juniper/grass association with a less dense canopy relative to Mountain Brush is typical of higher elevations.

Ponderosa Pine - Ponderosa pine forests are typical of higher elevations and higher annual precipitation. They are generally found above 6500 feet.

Vegetation cover is important in determining direct runoff, as the greater the vegetation cover, the less the runoff. "Cover density" (vegetation cover) is defined as the percent of ground surface covered by the crown canopy of plants and plant litter. The Arizona Highway Department procedure used in the study calls for three broad ranges of cover:

1)	poor	0 - 20% cover
2)	fair	20 - 40% cover
3)	good	more than 40% cover

The parameters for the analysis procedure were: soils, geomorphology, vegetation, and hydrologic calculations. Past experience has shown that the combination of these methods provides an effective and reliable means of delineating areas subject to periodic inundation (Clark, 1974 and Reckendorf, 1968).

Analysis of hydrologic characteristics, watershed configurations, drainage patterns, and vegetation were conducted using data in a step-down procedure from LANDSAT and high altitude aircraft flights. LANDSAT imagery was used at scales of 1:1,000,000, 1:500,000, and 1:250,000. High altitude aircraft color infrared imagery was used at scales of 1:120,000 and 1:60,000. Table 2 provides the complete list of imagery used.

Vegetation cover was estimated by imagery analysis and field checking. The ground-checked interpretation confirmed a close agreement between areas designated as flood hazard zones on the basis of vegetation analysis and those generated by hydrologic calculation.

While photointerpretive techniques based on vegetation analysis are highly useful for floodplain mapping in semiarid situations, ground observation or low altitude oblique views are important for refinement of the mapping. Assessment of tree condition in and near channels has a potential as a data source. Examination of

Table 2. LANDSAT and High Altitude Aircraft Imagery Used in Analyses

LANDSAT	**1716 - 1731[illegible]**
	1716 - 17305
	1717 - 17363
	1717 - 17360
	1678 - 17201
	1102 - 17274
	1102 - 17271

High Altitude Photography

Flight	Frames
73 - 056	0107
	0109
	0111
	0113
	0115
72 - 129	3929 - 3933
	3946 - 3948
73 - [illegible]	0011 - 0043
73 [illegible]	0023 - 0068
Mission 155 Roll 19	681 - 682

riparian growth by infrared photographic methods in a low-altitude oblique mode offers the possibility of partial elimination of ground-checks and the capability of coverage of large areas in a shorter time.

An additional vegetation-related factor which is worthy of inclusion in the analytical process is flood-deposited debris. This means of establishing high-water limits is obviously limited to ground-check observation, unless the debris is of considerable magnitude. This part of the vegetation-based method overlaps to some extent the historic data method.

Hydrologic Calculation

The procedures used in making the hydrologic calculations were basically those of the U. S. Department of Agriculture Soil Conservation Service (SCS), National Engineering Handbook, Section 4 Hydrology. A detailed, step-by-step process is presented in the SCS publication.

Hydrologic calculations were done based on valley cross-sections surveyed at two-to-three-mile intervals, and on the parameters include in the SCS discharge equation:

$$Q_p = \frac{484\ A\ Q}{\frac{D}{2} + .6T_c}$$

Where:

Q_p = peak discharge in cfs

A = drainage area in mi^2

Q = storm runoff in inches

D = storm duration in hours

T_c = time of concentration in hours

484 is a constant for units used

Values for variables in the previous equation were determined using curves in the SCS handbook. Data used in the curves were determined by analysis of

remotely sensed imagery with ground-check coordination. One of the variables of obvious significance is drainage area; as stated previously, this data was not available for most of the counties. The watershed map, which was one of the early products of this study, provided figures for drainage area. Time of concentration, which is the time required for water falling on the most hydrologically remote portion of a watershed to reach the point of concentration or discharge, was also obtained during the delineation of drainage patterns. Two additional factors which are necessary in order to obtain values for the component variables in the SCS equation are "curve number" and "soil hydrologic group." These values are the product of a complex set of relationships between four basic factors: (1) climate, mainly rainfall and temperature, (2) soil, its resistance to erosion and rate of water intake; (3) topography, length and incline of slope; and (4) vegetation canopy. Soil hydrologic groups, as defined by the Soil Conservation Service, are based upon the capacity of a soil to transmit water when the soil is in a saturated condition. A high rate of water transmission is associated with low runoff potential.

Soil hydrologic groups and curve numbers were evaluated using LANDSAT 70 mm chips in color infrared enhancement and high-altitude color infrared photographs in stereovision at 3x magnification. The bases for these interpretations were general slope class, soil reflectance as an erosion indicator and apparent density and condition of vegetation cover. Estimates of hydrologic groups were found to be in agreement with soil type-hydrologic group placements determined by SCS in most (approximately 85 percent) of the areas observed.

Floodplain lines generated by hydrologic techniques were assumed to be correct and delineations made based upon the various photointerpretive methods were measured against these lines. The confidence level with which one could interpret flood ways on the remotely sensed imagery far surpassed previously used hydrologic methods in delineating areas known to be subject to flooding.

COUNTY REPORTS

The analyses were done by personnel of the Applied Remote Sensing Program. LANDSAT imagery was used in black and white transparency form, at 1:1,000,000 scale for making interpretive overlays on bands 4, 5, and 7 separately. A 36-inch (1:250,000) color composite print of bands 4, 5, and 7 was used as a base for a land use map. All interpretations on the LANDSAT imagery were field checked for accuracy during the process.

Two sub-projects were developed based upon immediate need for compliance with the state mandate for local land use regulation. These were an inventory of existing uses of land within the county, and an analysis to estimate the extent of flooding hazards in urbanized areas and in areas of potential subdivision.

Graham County

Flooding from the Gila River in the vicinity of Safford, Arizona has occurred periodically since agricultural and urban development began in the early 1900's. This study has concentrated on the following in an attempt to delineate flooding potential in areas now devoted primarily to agricultural use but subject to development in the near future:

1. Delineate areas subject to inundation along the Gila River between Solomon and Pima by photointerpretive techniques (Clark and Altenstadter, 1974)
2. Compare inundated areas mapped from NASA high-altitude photography and ERTS to existing U.S.G.S. flood prone area maps
3. Produce maps of potential flood areas at 1:62,500 transferable by the Graham County planning staff to 1" = 500' county zoning maps for subsequent board adoption as the county's floodplain management program.

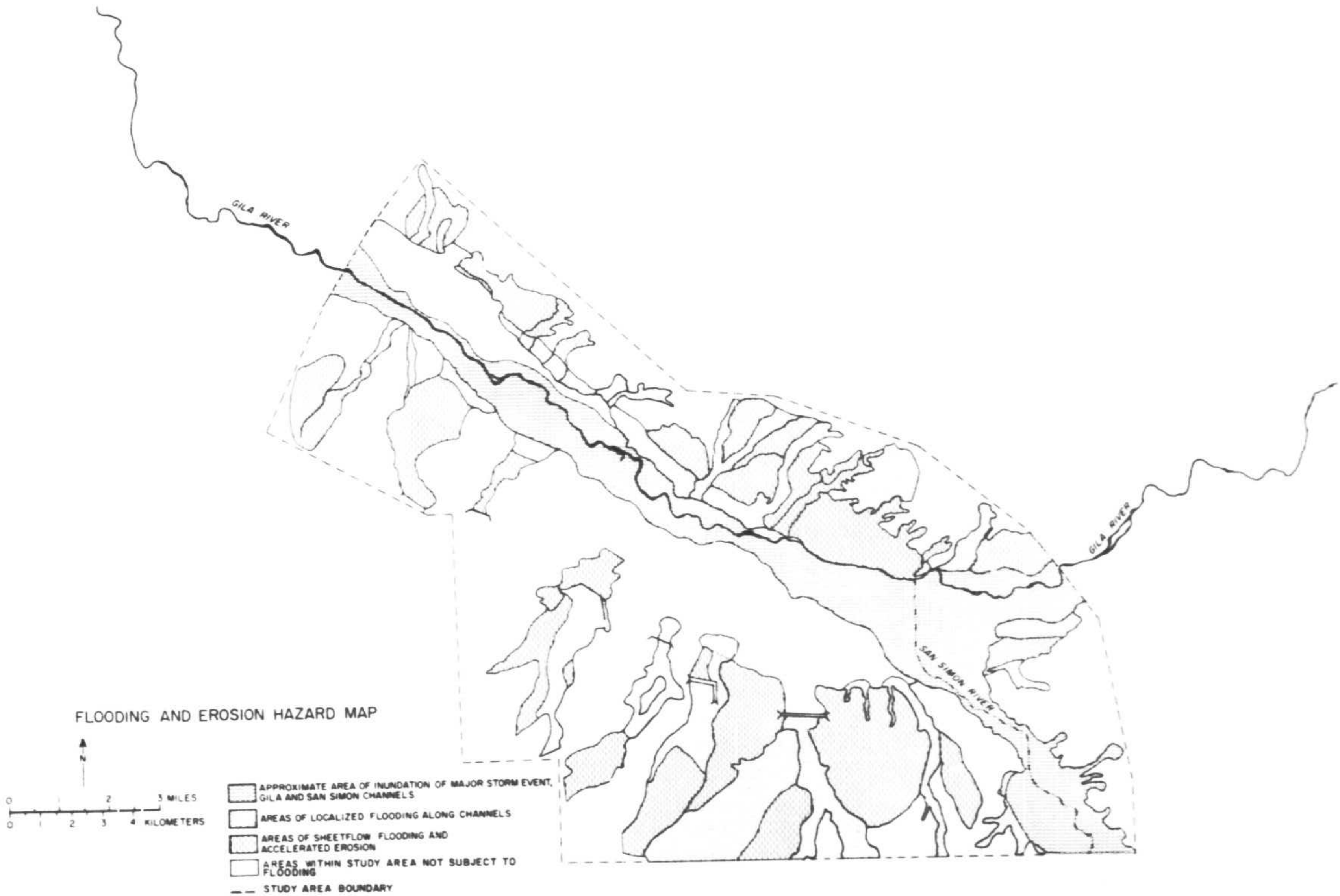


Figure 2. Graham County Flooding and Erosion Hazard Map

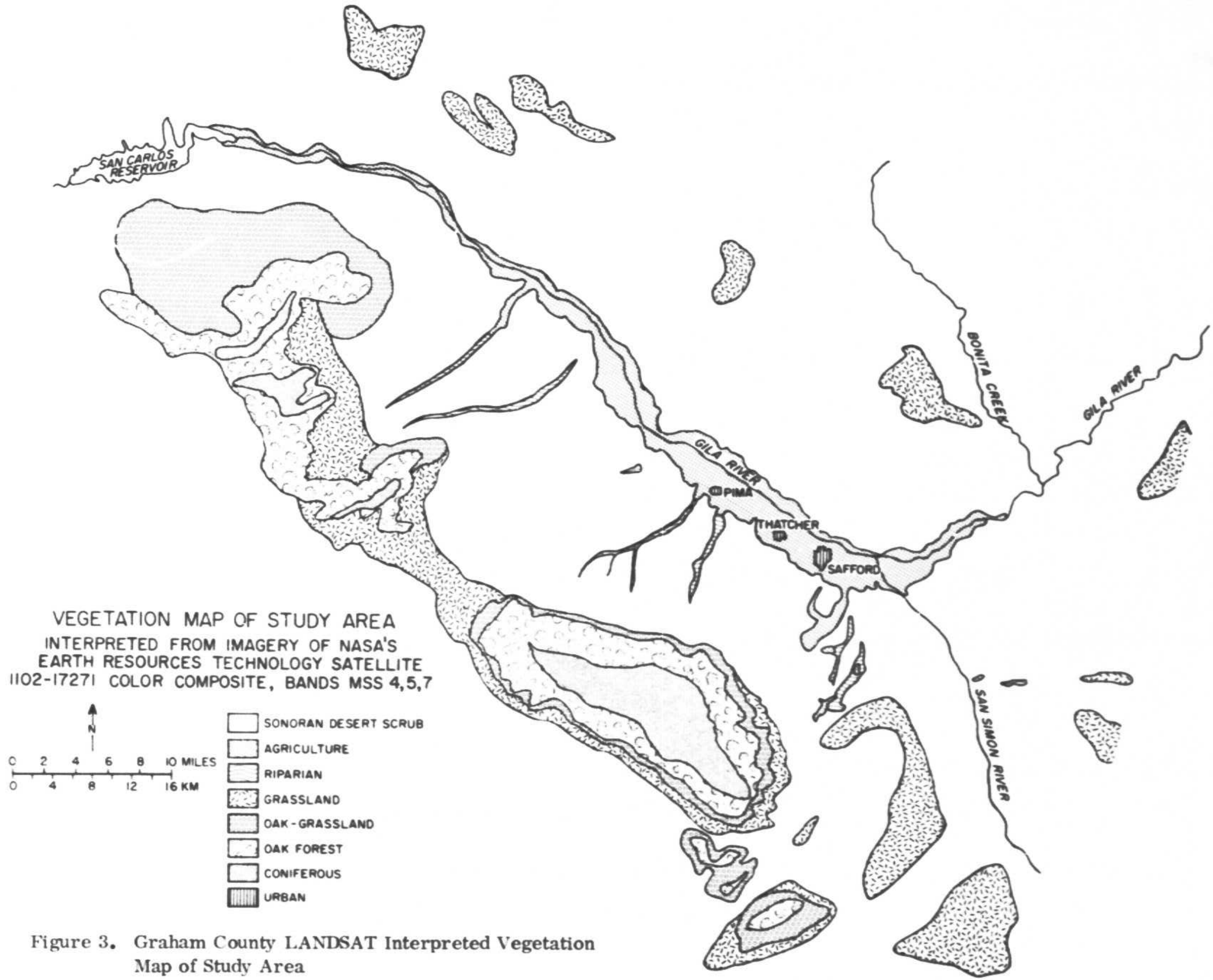
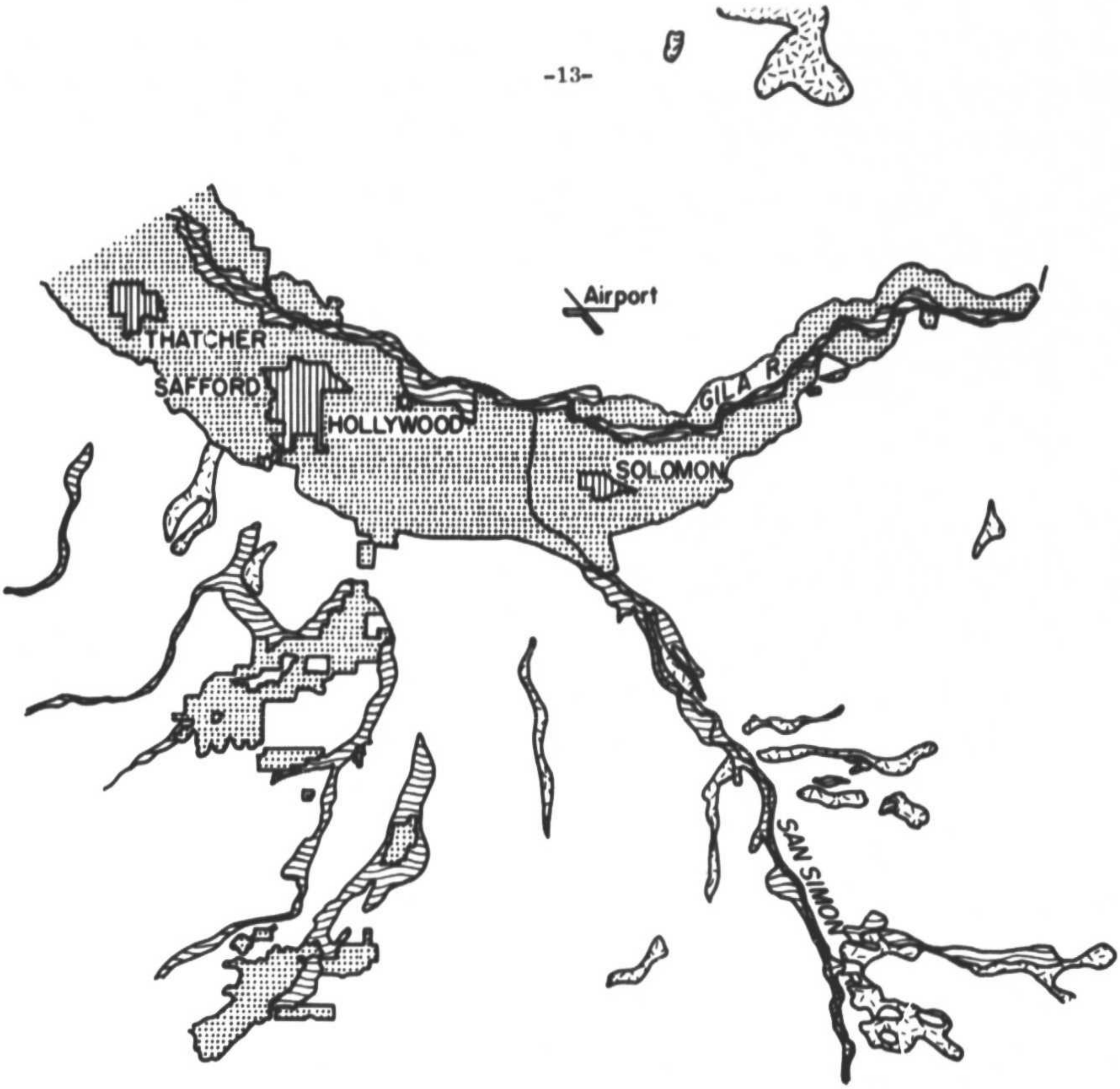


Figure 3. Graham County LANDSAT Interpreted Vegetation Map of Study Area



VEGETATION MAP OF STUDY AREA
INTERPRETED FROM NASA HIGH-ALTITUDE
AIRCRAFT PHOTOGRAPHY IN COLOR INFRARED
MISSION 72-129 1AUG72

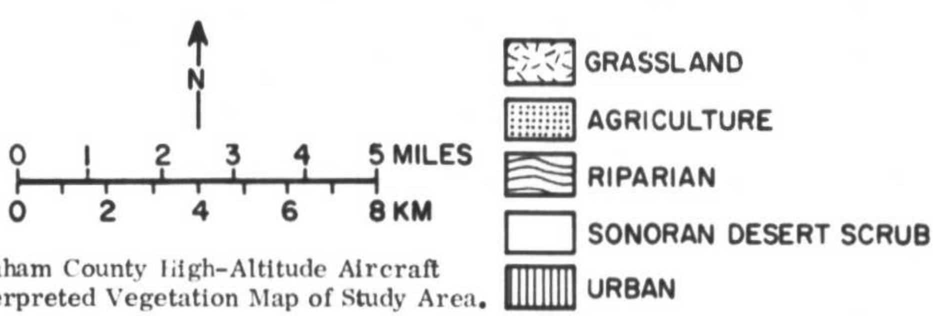


Figure 4. Graham County High-Altitude Aircraft Interpreted Vegetation Map of Study Area.

Additional input in the form of historic flood data from verbal and newspaper sources, and from known high water marks was incorporated into the analysis. This procedure was found to be unreliable as precipitation records and stream flow gauge records were inadequate. The lack of recorded data forced reliance upon the memory of area residents as to the height and reoccurrence of flood waters. This technique was not used in the other county projects.

Figures 2, 3, and 4 show the type of information produced in the study. The figures allow decision makers to compare existing land use to flood potential when decisions concerning new development on vacant land must be taken under advisement by the Board of Supervisors.

The need in Graham County was not only for flood and erosion hazard delineations to meet state legislative requirements but also for additional evidence toward settlement of a disputed inundation area boundary. The boundary which was provided for Federal Flood Insurance purposes was, according to county officials and to local history, an underestimation of the actual area subject to considerable flooding. Remote sensing-derived flood hazard mapping has enabled the county to appeal the erroneous delineation at minimal cost when compared to standard engineering procedures.

Yavapai County

Imagery from LANDSAT 1 and high-altitude natural color photographs were interpreted to develop land use (Figure 5) and flood hazard maps (Figure 6) for this central Arizona county. A county-wide land use map was made from 1972 and '73 Arizona Land Use Experiment photography, using black and white prints at 1:120,000 scale. Changes in agricultural and rangeland use patterns were interpreted from enlarged (1:250,000) LANDSAT color composites, and used to update the data derived from the U-2 flights, which were two-to-three years old.

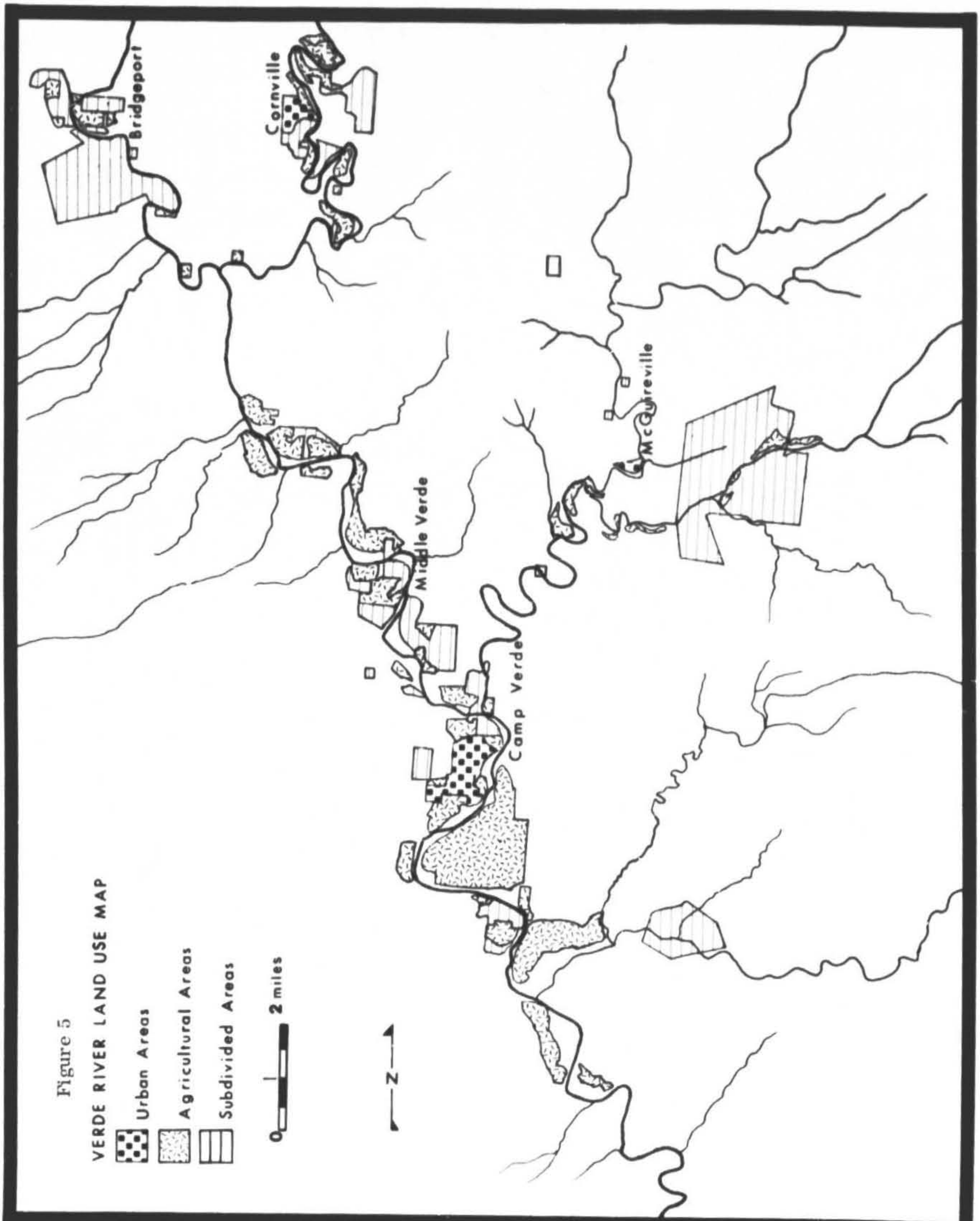


Figure 5
VERDE RIVER LAND USE MAP
Urban Areas
Agricultural Areas
Subdivided Areas
0
2 miles
N
Bridgeport
Cornville
McGuireville
Middle Verde
Camp Verde

Flood Hazard Map of the Verde River Interpreted from High Altitude Aircraft Photography, ERAP Mission 155, August 1971

☐ Area of localized Flooding Along Channels

▨ Area of Sheetflow Flooding and Accelerated Erosion

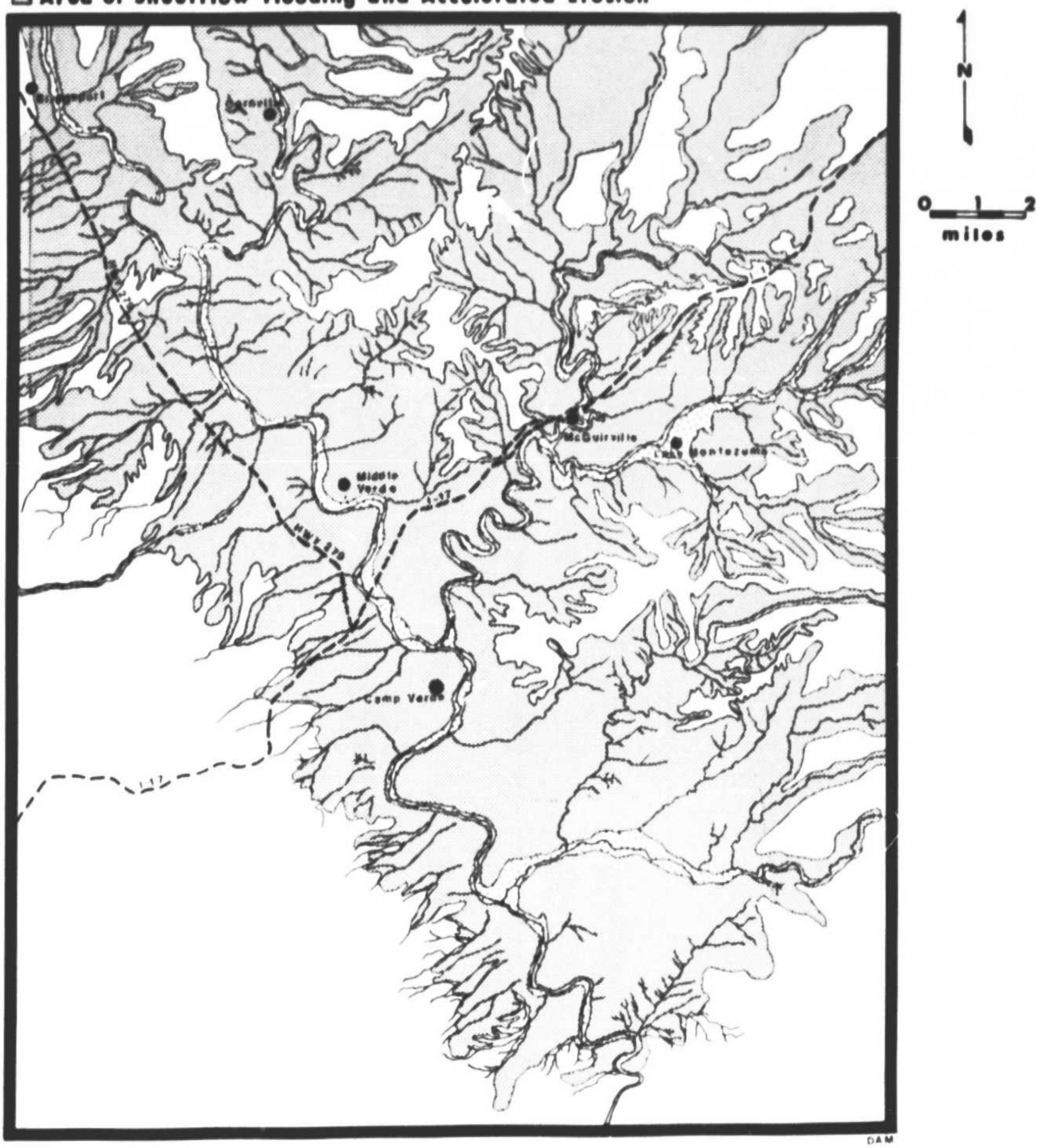


Figure 6. Verde River Flood Hazard Map

The area selected for flood hazard analysis is the rapidly urbanizing region surrounding Camp Verde and Cottonwood along the Verde River, Wet Beaver Creek, and West Clear Creek drainages. This area is under pressure of speculative land subdivision, and has a history of severe flooding on the major channels and ephemeral streams. Some subdivided land in the study area lies within the main channel of a large stream.

Natural color 9-inch transparencies acquired from RB-57 Mission 155 was utilized as the data base. Overlays were made on the transparencies to delineate stream channels, over flow areas adjacent to channels, areas of sheet flow or surface scour, and areas apparently unaffected by flooding and accelerated erosion. All interpretations were field-checked and modified as necessary.

The watershed of West Clear Creek was selected for a more intensive land use and floodplain study. This area is under very intensive subdivision pressures. Many structures in these subdivisions lie within the floodplain of West Clear Creek and may be susceptible to flood damage. Forest Service imagery at 1:31,600 was used for this project.

The larger scale and high resolution qualities of the imagery enabled the operator to make very accurate interpretations of flood hazard areas (Figure 7) and land use patterns (Figure 8). The same procedure was followed in delineating the floodplain and the land use in this area as was used in the U-2 interpretations.

The results of this study are to be used by the planning staff of Yavapai County in an attempt to impose a set of guidelines on what has been a situation of land use dominated by economic expediency. Remote sensing has provided the basis for planning in a rapid growth area by virtue of a broad overview of land use interrelationships and a reasonably fast update capability. Land use data developed by this project will become a base from which county officials can direct the growth of the area in such a way as to maximize the benefit derived from existing social

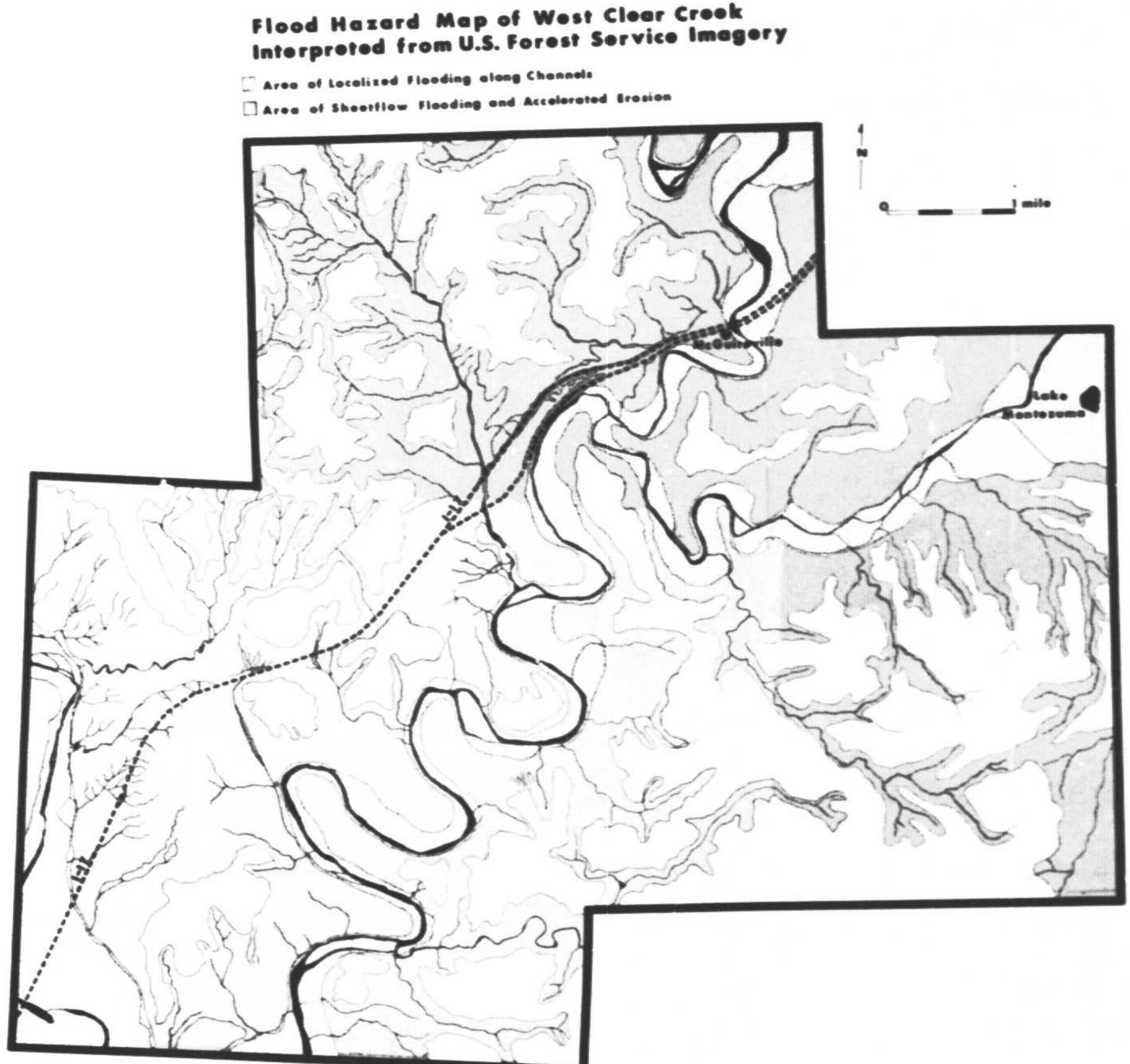


Figure 7. West Clear Creek Flood Hazard Map

Land Use Map of West Clear Creek Interpreted from U.S. Forest Service Imagery

Figure 8. West Clear Creek Land Use Map

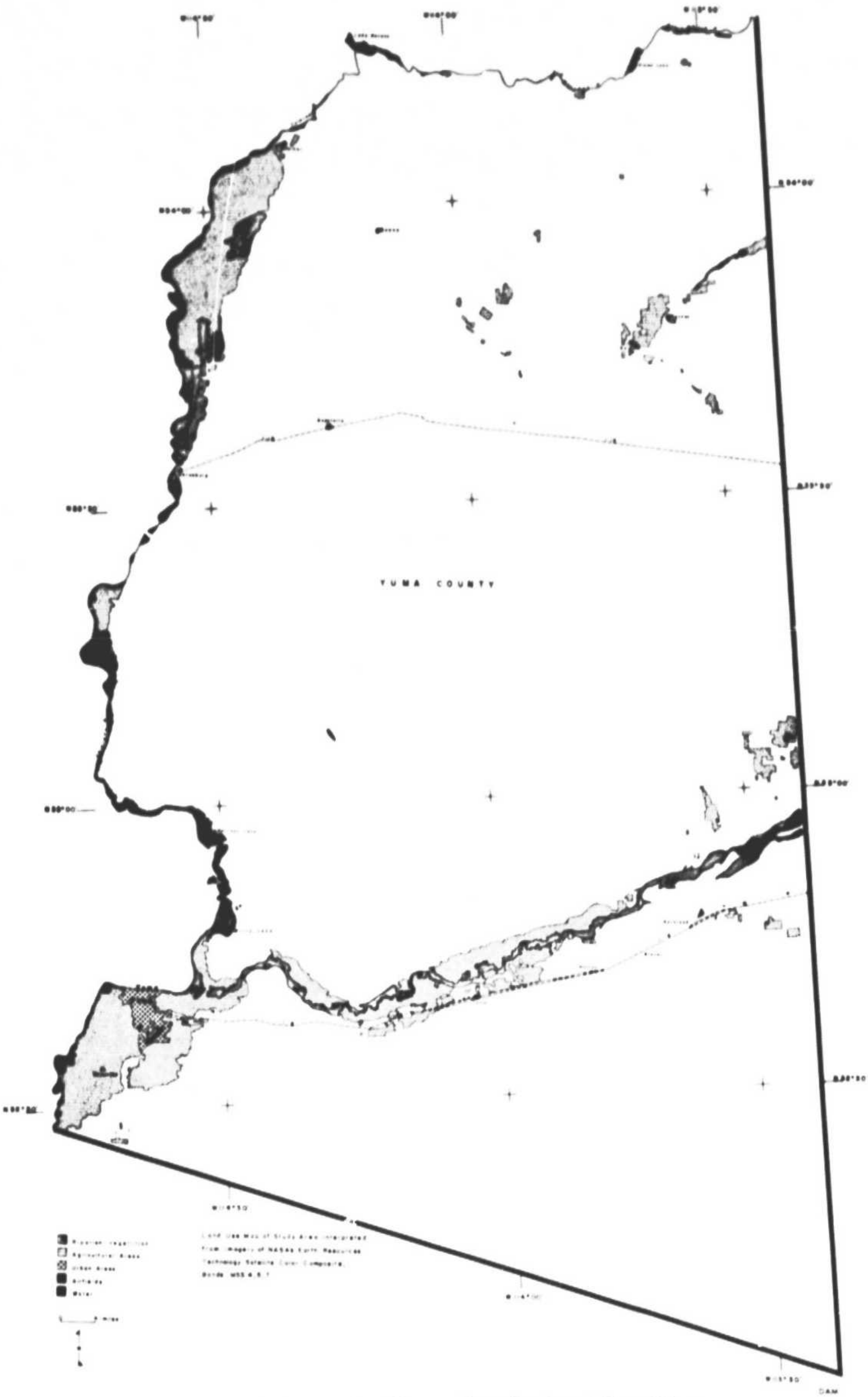


Figure 9. Yuma County Land Use Map

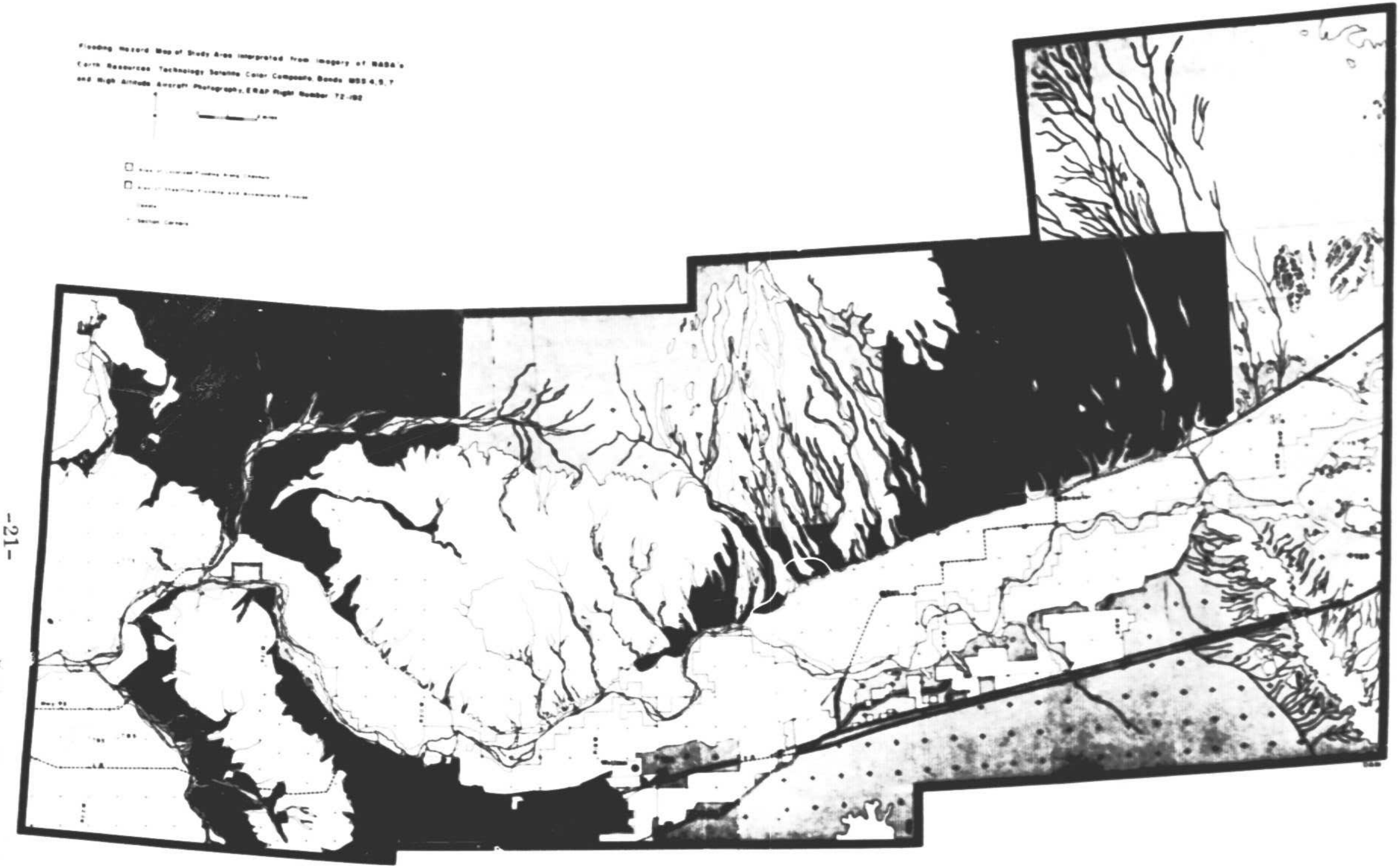


Figure 10. Yuma County Flood Hazard Map

services and utilities while avoiding potentially dangerous flood hazard areas and the excessive costs involved with development of such lands.

Yuma County

Yuma County, in the extremely arid southwestern corner of the state, shares in the problems of other rural jurisdictions: rapidly changing patterns of land use--some of it in areas environmentally unsuited for development, and very little data upon which to base planning decisions or long-range planning objectives. The development of land use overlays (Figure 9) as documented above was necessary in order to provide the county planning staff with basic, up-to-date locational data. A continuing problem in southern Yuma County is the subdivision of prime agricultural property along the Gila River. The net effects of this situation are the removal of land from production and the placement of development in the easily developable, but flood prone valley of the Gila. By identifying flood hazard areas (Figure 10) much of this land can be zoned for agricultural and related uses, thus being maintained in production without the threat of land speculation.

Apache County

The Apache floodplain analysis (Figure 11) included production of a mosaic of the study area using black and white prints from flights 73-124 and 73-174 of the Arizona Land Use Experiment. The prints used in the mosaic were at a contact scale of approximately 1:120,000. Unfortunately, there is no color infrared coverage of the study area; such film would have served to increase the efficiency and accuracy of interpretations. The 1:120,000 mosaic was used to refine the geomorphology, vegetation, soils, and erosion interpretations made from the LANDSAT composite. Additional data were extracted from the mosaic for the smaller stream channels which were less than the resolution capability of the satellite imagery.

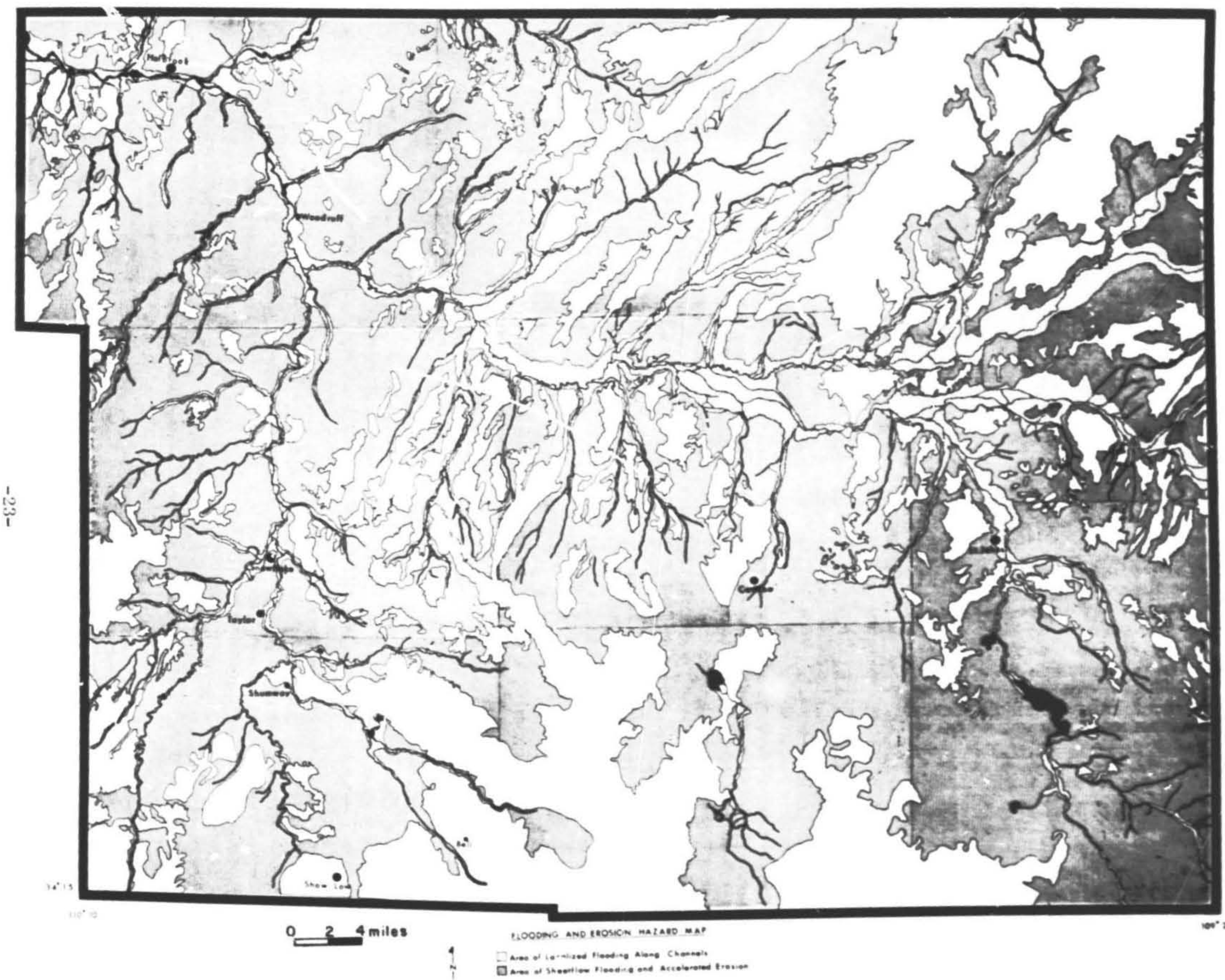


Figure 11. Apache County Flood Hazard Map

Figure 12. Apache Land Use Map

The product of this study is a set of topic maps (Figures 11 and 12) which will be used by the planning staff of Apache County in their process of land use regulation. The land use map will provide a base from which a subdivision development can be monitored. The flood hazard map will be used by county planners to direct new urbanization away from areas which are subject to periodic inundation and to comply with state and federal legislation which makes the mapping of flood prone areas mandatory for insurance purposes.

The land use and flood hazard maps have been presented to the County Planner's office for immediate use in the comprehensive land use regulation process. Data presented on these overlays will be used by planners for checking new subdivisions for compliance with drainage regulations and for monitoring growth trends and extent of land development.

RESULTING POLICY DECISIONS

The interaction of the ARSP team with Apache, Graham, Yavapai, and Yuma Counties represents a concentrated effort to work within the rural counties of Arizona. These counties share a common problem in that each is predominantly rural, but experiencing a rapidly expanding population. In each case the county has a planning directory who advises a Planning Commission and Board of Supervisors in their policy decisions regarding orderly, planned growth. For example, Yuma County in Southwestern Arizona is one of the prime agricultural areas in the entire state. The quantity of cotton, feed grains and vegetables produced in this area surpasses all other areas in Arizona. Yuma County also borders on the Colorado River, and thus is a prime area for new development of retirement communities and for weekend boaters interested in the area for water recreation. This situation is resulting in the removal of prime agricultural land from production and replacement with new subdivisions.

The land use mapping and identification of flood hazard areas will allow Yuma County to delineate agricultural areas that are not flood prone and possibly suited for development, while also protecting the flood prone farming areas from development, and therefore maintaining high agricultural production.

Tentatively, the Board of Supervisors is planning to adopt a land use resolution calling for the protection of all agricultural areas in the designated flood prone area of the lower Colorado and Gila Rivers. These areas will remain free from intense development and will be utilized for intensive agriculture. Those agricultural areas lying outside the flood prone areas may opt for development if the owner desires.

Comprehensive, long-range plans are being developed in Apache and Yavapai Counties, both of which are experiencing rapid growth in remote areas of their jurisdictions. In Apache County, problems for the county planner have arisen from the subdivision of large ranches in the southern half of the county. This land, while physically attractive to persons seeking recreational sites is in a geomorphologically active area of erosion and is subject to flooding hazards. By applying data acquired by satellite and high-altitude aircraft, ARSP has been able to supply the county planner with an effective tool for the control of potentially dangerous and costly land use activities.

Problems of a similar nature exist in Yavapai County, which has had considerable growth along the Verde River and West Clear Creek drainages. In these areas, much of the higher land is dissected by minor channels on slopes too steep for concentrated development. Urbanization has taken place in retired agricultural areas subject to periodic inundation. In many cases, lots are sold to persons from outside the Southwest who are unfamiliar with the flooding potential of the ephemeral streams of arid and semiarid regions. Flood and erosion hazard maps on file at the office of the County Planning Department will enable persons considering land purchase to examine their property in relation to these environmental hazards. The

interpretations developed by ARSP for Yavapai County will be acceptable to the Arizona Water Commission, for initial compliance with mandatory floodplain management regulations.

A problem common to all of the rural Arizona counties which have had interactive projects with ARSP is the subdivision of remote areas without application for planning department approval or submission of a plat. Such illegal subdivisions create a financial burden on county government, both in loss of potential fee and tax income and in the eventual costs of providing county services and enforcing land use laws after the fact. By use of remote sensing techniques, county planners have obtained timely and cost-effective information on the status of land within their areas. Current and accurate information on the status of subdivisions is essential to the county planning staff who are charged by the state government with the responsibility for rational planning decisions, but who have neither the personnel nor the funds for such activities.

Graham County, in Southeastern Arizona, has a history of costly flooding in the area adjacent to the Gila River, between the towns of Solomon and Pima. The area shown in Figure 3, the town of Hollywood, has not yet recovered from damages suffered during a storm in November, 1972. The flood hazard map developed by ARSP for Graham County will be used to direct new development away from areas subject to inundation. The need for such regulation in the project area is immediate due to increasing population pressure as a result of rapid expansion of mining in the area. As a result of the ARSP project there exists now a data base for ordinances controlling further development of flood prone lands.

A small planning department is incapable of making the large-scale inventory that was made with the utilization of remote sensing. These projects, in which the ARSP program has worked, signify the utilization of remote sensing at the truest grass roots level. The larger more densely populated counties, such as

Maricopa and Pima in which Phoenix and the Tucson metropolitan areas are located, have the planning capability and staff necessary to carry out their own projects. This is not the case with the counties in which the program has worked during 1974 and 1975. People who are serving on the Boards of Supervisors of these counties are predominantly ranchers, farmers and businessmen. Their exposure to advanced technology such as remote sensing and its applications to date has been minimal. The work done by the ARSP program is a technology transfer process whereby the products derived from remote sensing are utilized in a positive and meaningful way, in outlying areas to provide project information desperately needed by community leaders.

ACKNOWLEDGEMENTS

This study was funded jointly by the National Aeronautics and Space Administration grant NGL 03-002-313 and Graham, Yuma, and Yavapai County Planning Departments. The orthophotoquads used in the analysis were loaned by the Arizona Resources Information System (ARIS), directed by C. C. Winikka.

Jim Altenstadter and Robin Clark pioneered the techniques used in the flood hazard analysis. Their original work has been published in OALS Bulletin 6 "Application of Remote Sensing Techniques in Land Use Planning: Floodplain Delineation."

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Mr. Robert Baldwin	-	Yuma County
Mr. Arlo Lee	-	Apache County
Mr. James Moser	-	Graham County
Mr. Jerry White	-	Yavapai County

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